National Center for Research Resources

Biomedical Technology Area

Safety Site Visit Report
May 4, 1999
Of the National Tritium Labeling Facility

Lawrence Berkeley National Laboratory, Berkeley CA

Overall Assessment I: Doses and Risks to the Community

Overall, it is clear that the radiation exposure, and the associated radiation risk, to the community from the activities of the NTLF is extremely small. The "bottom line" in terms of radiation-associated health risks to any individual is the equivalent dose of radiation to which that individual is exposed. The NTLF staff estimate, both by calculations, and by direct measurement which confirm the calculations, that the maximum lifetime dose, due to tritium emissions from the NTLF, to a (hypothetical) individual both living and working for his/her entire lifetime at the perimeter of the NTLF is less than 1 mSv. For comparison the lifetime radiation dose from natural sources (radon, cosmic rays, etc) is about 250 mSv.

The cancer risk associated with a lifetime exposure to 1 mSv is about 1 in 20,000. Individuals living and/or working further from the NTLF facility (e.g. 1 – 2 km away) receive much smaller lifetime doses (<0.1 mSv), and the corresponding cancer risks are correspondingly smaller (less than 1 in 200,000). Individuals living in the local community, as a whole (beyond 2 km) receive lower lifetime doses (<0.015 mSv) and their lifetime cancer risks due to NTLF emissions are less than one in one million.

The other relevant risks associated with the NTLF emissions are hereditary defects in the offspring of exposed individuals, and risks to individuals exposed *in utero* (teratogenic risks). The risks of hereditary defects are likely to be about one tenth of the carcinogenic risks - about 1 in 200,000 for an individual living and working immediately adjacent to the NTLF facility, about 1 in 2 million for individuals living and working between 1 and 2 km from the facility, and about 1 in 10 million for individuals in the local community as a whole.

Teratogenic risks (from exposure to the developing embryo or fetus) are expected to be extremely small, due to the low exposure times to the embryo or fetus. For example, the dose to the embryo/fetus resulting from an individual spending a full nine months at the perimeter of the NTLF would be about 0.02 mSv, and the corresponding risk of teratogenic damage would be about 1 in 100,000. Spending less time at the perimeter of the NTLF would reduce these risks. For example, spending 100 hours at the perimeter of the facility and the remaining gestation period at a distance of 1 km would reduce the teratogenic risk to about 1 in one million.

The risk estimates quoted here have uncertainties attached to them, related both to uncertainties in the doses to individuals and to uncertainties in the risk estimates for a given dose. The dose estimates have been validated by comparison with urine measurements from workers in the adjacent Lawrence Hall of Science, which have been independently analyzed by U.C. Berkeley and by an independent company. Measurements of Lawrence Hall of Science workers living both off campus and for one worker living near the NTLF, gave results very close to those predicted by the NTLF estimates. This gives the Committee confidence that the doses estimated by the NTLF staff are unlikely to differ from the true doses by more than a factor of 2. In other words, the true doses could be as much as twice as high, or as little as twice as low, as those estimated by the NTLF staff.

Regarding the risk estimates for a given dose, these are ultimately derived from measured risks in A bomb survivors at Hiroshima and Nagasaki. It is clear that prolonged low-level tritium exposure represents a significantly different situation from that of the A-bomb survivors. However there is little evidence that these differences would result in significantly increased risk estimates. Specifically, the protracted exposures of relevance to NTLF emissions would most likely result in decreased risks for a given radiation dose – there is much evidence that protracted exposures are less hazardous than short exposures to the same dose, because the DNA damage has more time to repair. The effects of the different type of radiation (beta particles for tritium vs. gamma rays from the A bombs) are unlikely to result in differences in biological effect (per unit dose) of more than a factor of 2.

In summary, the risks associated with NTLF emissions can be said with a considerable degree of certainty to be very low, with a maximum cancer risk of about 1 in 20,000 for a (hypothetical) individual spending his/her entire life at the perimeter of the NTLF facility. Making all possible pessimistic assumptions, this risk could be as high as 1 in 5,000 (or as low as 1 in 80,000). Risks for individuals spending significant time further from the NTLF facility are significantly lower. Risks to individuals (including pregnant women and the developing embryo/fetus) visiting the Lawrence Hall of Science are exceedingly small, due to the comparatively short periods of time spent there.

While the risks from NTLF emissions are very small, good practice mandates that the NTLF is and continues to be committed to continual efforts to reduce the annual tritium emission rates from the facility; in general both the NTLF staff and the LBNL staff have demonstrated a commitment to this end. Specifically, the tritium emissions in 1999 are at least ten times less than those of 1989. Despite this significant improvement, the Committee did identify various areas where further improvement could and should be made, as now discussed.

Overall Assessment II: Recommendations

The most notable issue relates to a the lack of a full time health physicist on the NTLF staff, dedicated to working to reduce tritium emissions. While the co-PI, Dr. Williams, is capable of performing this task, his numerous other commitments have not allowed sufficient time to work on this issue. The other NTLF staff members are strongly orientated towards their own research and do not appear to have the time nor the expertise to carry through a long term program continuously working towards emission reductions. This issue is exemplified by noting that there was a steep decrease in tritium emissions around 1990, due to changes in procedure, and apparently (though reliable data are not yet available) another steep decrease in emissions in 1999, but there was little significant improvement in the intervening years. It is strongly recommended that the NTLF has on staff a full time doctoral-level health physicist, whose prime responsibility would be to work with Dr. Williams to develop and undertake a continuous ongoing program to improve equipment/procedures, with the goal of decreasing tritium emissions.

A second issue of some concern lies in the current inability of the NTLF to perform accurate inventories of annual tritium inflow vs. outflow, in order to provide a direct independent validation of the quantity of tritium released into the environment. Such a capability is viewed as extremely important, both in terms of good practice, and in terms of overall credibility. Both equipment and staff (see above) would be required to implement this capability, but it is strongly recommended that it be done.

A third issue of concern relates to independent oversight of the safety aspects of the NTLF. While it is true that various government agencies and internal committees have reviewed the facility at regular intervals, it was apparent that their role has been primarily to ensure that the NTLF operates within legal limits. While these committees adequately perform this role, there is a clear need for a committee to oversee and ensure a continuous ongoing program aimed at reduction of tritium emissions. LBNL and NTLF leadership appear to recognize this need, with the formation of the NTLF Resource Technical and Safety Advisory Committee. However, the Committee has not been effective, having met only three times in the past five years, and consisting largely of LBNL employees. It is recommended that this Committee be reconstituted by the LBNL director, with a mandate to oversee a continuous ongoing program aimed at reductions in tritium emissions over time. It is recommended that the Chair of the Committee be an eminent external physicist or medical physicist from outside LBNL, that the majority of the committee be from outside LBNL, that the Committee should meet for at least one full day every year, and that complete minutes be recorded, including Committee recommendations.

A fourth issue relates to the probability of accidental releases. No estimates of the probability of accidental releases has been made, and given the comparatively large inventory of tritium at the NTLF, process hazard analysis techniques could appropriately be used to help identify process areas that may result in an accidental release, and help suggest modifications to improve process safety. NTLF staff stated that such analyses were not required under current regulations, which is true, but the 1998 accidental tritium release would suggest the advisability of such studies.

A technical recommendation relates to the tritium level in the NTLF facility at which an alarm is set off. The current level is 1 DAC, a regulatory limit, and the Committee recommends that this should be set lower, perhaps at 0.25 DAC, particularly to reflect the NTLF commitment to always being well below regulatory limits. While the NTLF staff suggested that this level was too close to background levels from, for example, radon, the Committee felt that as the measurement systems are computerized, appropriate background subtraction techniques could be applied, particularly as the time constant for background fluctuations is likely to be at least of the order of hours. Alternatively, a proportional counter could be used to allow background filtration using rise-time discrimination. Again, a dedicated health physicist on staff would be helpful here.

Finally, the Committee found that the entire NTLF staff to have a high level of expertise, and a strong commitment to safety issues. In particular, Dr. Williams – who is de-facto in charge of safety issues – showed a highly impressive knowledge of the issues, and a vision of future progress – tempered only by his numerous other commitments.

Specific Topics

Institutional Commitment and Organizational Structure

The institutional commitment to safety at the NTLF is clearly present. Within the NTLF, Dr. Williams shows an impressive grasp of the issues. Within the LBNL as a whole, the Director, Dr. Shank, also articulated a strong commitment to safety issues, which has been backed up by support from the Environmental Health and Safety Division (EH&S), both in terms of personnel and equipment.

The complex organizational structure within LBNL, while ensuring clear compliance with appropriate regulatory requirements, may not provide the ideal environment for a continuous ongoing proactive program aimed at tritium emission reduction; in practice – and probably appropriately – this initiative has come from within the NTLF rather than from the health physicists within EH&S. As discussed elsewhere in this report, NTLF does not, however, contain a dedicated doctoral level health physicist, the presence of whom would clearly facilitate the on-going long-term emissions reduction program.

Health Risk Assessment from NTLF Emissions, and Validation

In 1997 LBNL produced a document entitled “Environmental Risk Assessment for Tritium Releases at the NTLF at LBNL” (LBL-37760). The first author, Dr. McKane, presented this work to the committee. Essentially the work consisted of 2 parts:

a) estimating doses to individuals at different locations for a given release of tritium (e.g., 100 Ci/y).

b) estimating the health consequences of these doses.

The dose estimates in LBL-37760, while prima facie reasonable, are based on numerous assumptions, and ultimately require validation based on measurements of airborne tritium and, crucially, bioassays (tritium in urine measurements), both in workers and the public. This validations has been done, and the measurements do confirm that the dose estimates in LBL-37760 are reasonable. The Committee estimates that the doses estimated by NTLF are good to within a factor of 2 (i.e. the true doses could be as much as twice or as little as a half of those estimated). Within this range of uncertainty however, it is clear that the radiation doses to the public from NTLF emissions are very small, even for a hypothetical individual living and working on the perimeter of the NTLF.

The risk models used in LBL-37760 to convert equivalent dose to risk, both carcinogenic, mutagenic, and teratogenic, are reasonable. Some of the assumptions used are probably somewhat conservative, but this is not inappropriate for a risk assessment exercise. The Committee estimates that the risk estimates used (per unit dose) are probably good to within a factor of two. Together with the uncertainties in the dose estimations, this would imply that the true overall risk estimates due to NTLF releases are good to within a factor of 4 (i.e. they could be up to four times higher, or up to four times lower). Even if all conservative assumptions are made, and it is assumed that the risks are actually four times higher than estimated in LBL-37760, the risk to an individual living and working on the perimeter of the NTLF would still be very small, and the risks to individuals living/working further from the NTLF would be exceedingly small.

Radiological Work Authorization

Dr. Zeman discussed the "LBNL Radiological Work Authorization" (RWA). This work authorization program insures that each project in which radioisotopes are used is reviewed periodically and that appropriate procedures for the safe use of the material are established. Each project is assigned a hazard level rating based on the amount of activity used, the relative toxicity, the time used and the complexity of the procedures. The permit for the NTLF is assigned a level III which is the highest hazard level and requires that the operating and safety procedures be described in detail. The details described in the RWA provide the elements essential for the safe handling and monitoring of high tritium levels as well as addressing procedures necessary to minimize releases to the environment. Dr. Philip Williams is the PI who holds the RWA for the NTLF and it was clear from his talk that he is fully aware of and committed to his responsibilities under the RWA. This is further supported by the fact that doses to workers have consistently been less than 10% of the regulatory limit.

Tritium Emissions to the Environment and Progress in Reducing Emissions at NTLF

Total tritium releases per year to the environment between 1970 and 1995 have averaged about 138 Ci. The primary point of release as determined by monitoring has been through the stack located on the hillside beside Building 75. Also, there are some releases to the sanitary sewer system which by regulation must be less than 5 Ci/y. Monitoring of releases to the sewer show that the average amount released per year is less than 1 Ci. Monitoring of soil and vegetation near building 75 has revealed measurable levels of tritium. Monitoring wells have been located at a number of sites near building 75 in order to determine the extent of measurable levels of tritium in soil and ground water. The monitoring results show that tritium is not spreading up the hill or to either side and likely not moving down the hill. These conclusions are based on measurements made in monitoring wells since 1990. Originally, there were 4 monitoring wells. Since then additional wells were added to make a total of 37 wells. It was only after the addition of these new wells that some tritium was found further down the hill than originally believed based on the results from the four wells. However, the original wells were not in a location where this activity could have been detected. The staff of NTLF believes that the tritium contained in the presently defined area is not moving due to the peculiar hydrology of the site. The site consists of fill-dirt placed in a depression and the soil of the original site appears to be resistant to tritium spread. They further estimate that the total tritium in this area is about 1 Ci. Sampling also indicates the presence of tritium in the vegetation and duff near the stack.

In 1990 an extensive modification of the tritium labeling vacuum lines was made to recover tritium gas on a bed of uranium. In addition, new pumps were installed that use essentially no oil and thereby eliminating contaminated oil as a waste product. Prior to 1990, emissions were higher than at present with a peak emission of about 570 Ci in 1988.

Although the fraction of processed activity that is released to the environment is low and the resulting site doses well below regulatory limits, the staff of NTLF have looked for practical ways to further reduce emissions in accordance with the ALARA principle. The staff has recently designed and has begun testing a system that will convert any tritium not captured for recycling into water. This is expected to result in a large decrease of tritium released from the stack. Stack tritium levels measured during recent labeling procedures have provided preliminary support for this expectation. The implementation of this new process should result in major reductions in emissions to the environment.

Tritium Waste Management

The Waste Management Group of LBNL and the NTLF staff share waste management responsibilities at the NTLF. The NTLF generates both low level radioactive waste (LLRW) and mixed waste (MW). The LLRW is sent to the Hanford, WA site for disposal. Mixed waste is treated off-site at the Idaho National Engineering and Environmental Laboratory (INEEL). The NTLF has also designed an on-site mixed waste treatment process that captures oxidized tritium in a way that INEEL's incinerator does not and therefore, greatly reduces tritium emissions into the air. The NTLF deserves commendation for developing this process, which is an improvement in current technologies for processing tritium mixed waste.

The Committee also agrees with and applauds the NTLF on its current practice of capturing and recycling most of the tritium left after tritiation for return to DOE facilities for disposal/recycling. This practice tremendously reduces the amount of tritium that would otherwise have been included in the facility's air emissions or mixed waste. The practice has resulted in the drastic reduction of the tritium emissions into the air from the facility's stack since 1990.

There is some concern that the NTLF does not have the capability of analytically determining the amount of tritium that is recycled this way. The NTLF therefore has to rely on the DOE Facilities that receive the captured tritium to quantitate those shipments. When the quantitation is not performed by the receiving DOE Facility, reconciliation of NTLF tritium inventories becomes difficult. The inventory reconciliation problem this poses, probably does not compromise the ability of NTLF to keep track of the disposition of the tritium it receives and works with. This is done through extensive inventory listing, process knowledge, characterization of waste, and extensive monitoring of processes, stack emission, personnel and the environment. However a more direct approach to the inventory issue would certainly be good practice, to provide a check on undetected releases.

Accidents

On July 24 1998, an accidental release of tritium occurred at the NTLF. This resulted in the release of an estimated 35 Ci of tritium into the air at the NTLF emission stack. The LBNL undertook an extensive review of the accident including estimates of dose to the public from the release. The dose to the public from the release was very small. Even though the NTLF was not required to report the accident, because of the dose involved, it voluntarily reported the incident to the DOE. The Committee received assurances from NTLF officials that the process that resulted in the accident has been discontinued.

No estimates of the probability of accidental tritium releases has been performed, which would parallel the studies performed regarding routine releases. Given the comparatively large inventory of tritium at the NTLF, the use process hazard analysis techniques could appropriately be used to help identify process areas that may result in an accidental tritium release, and help suggest modifications to improve process safety. These techniques include preliminary hazard analysis (PHA), failure modes and effect analysis, (FMEA), fault tree analysis (FTA), event tree analysis (ETA), and hazard and operability studies (HAZOP). Dr. Williams stated that such analyses were not required under current regulations, which is true, but the 1998 release would suggest the advisability of such studies. Again, a dedicated health physicist on staff would be important here.

Investigators

The PI of this program is Dr. Wemer and the co-PI Dr. Williams. All the NTLF staff showed a clear commitment to radiation safety issues, though the leadership role in terms of long-term emission reduction is clearly with Dr. Williams. Dr Williams' knowledge of the issues is outstanding, and the significant improvements in tritium emission levels can be attributed to his leadership. As discussed elsewhere in this report, Dr Williams' other commitments may well underlie the lack of reduction in tritium emissions between 1990 and 1998, and the need is apparent for a full time doctoral level health physicist at the NTLF to work with Dr. Williams to design and continue the ongoing program dedicated to achieving reductions in tritium emissions.

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